GÖTEBORGS UNIVERSITET

INSTITUTIONEN FÖR KOST- OCH IDROTTSVETENSKAP

Anthropometric and physical profiles in elite and sub elite Swedish male soccer players

Patrik Andersson
Simon Meander
Josefine Sinclair

Kandidatuppsats 15 hp
Program : Sports Coaching
Vt 2016
Handledare: Lennart Gullstrand
Examinator: Anders Raustorp
Rapportnummer: VT16-33

INSTITUTIONEN FÖR KOST- OCH IDROTTSVETENSKAP

Kandidatuppsats 15 hp

Rapportnummer:	VT16-33
Titel:	Anthropometric and physical profiles in elite and sub elite Swedish male soccer players
Författare:	Patrik Andersson, Simon Meander & Josefine Sinclair
Program:	Sports Coaching
Nivå:	Grundnivå/Avancerad nivå
Handledare:	Lennart Gullstrand
Examinator:	Anders Raustorp
Antal sidor:	34 (inklusive bilagor)
Termin/år:	Vt2016
Nyckelord:	Anthropometric profile, body composition differences, elite, isometric strength, mobility, physical, physical profile, soccer, sub-elite

Abstract

Soccer is a popular team sport played by children, adolescents, men and women across the world. The game requires multiple physical skills such as endurance, strength, mobility, rapid change of direction and running pace. Elite soccer players train these abilities to enhance performance, prevent injuries and to cope with the training and competition volume. This paper compares anthropometric and physical profiles of an elite- and a sub-elite team from the same Swedish soccer club. The purpose is to determine possible differences and locate areas of improvement in the process of preparing the sub-elite players for transition to the elite team. A significant difference in body fat (Elite: 13.3 ±2.6 vs Sub-elite:15.6 ±2.7 %) and lean body mass (66.4 ±7.6 vs 59.9 ±3.8 kg) was found. Significant differences in mobility in both left (147.1 ±8.5 vs 157.1 ±4.7°) and right (145,1 ±8.4 vs 155 ±4.1°) quadriceps was also sown in the results. No significant difference was found in strength between the two groups. Age and active years in the sport could explain the difference in body composition. The sub-elite team reported more training hours than the elite team which most likely generates equal strength in both groups. It is possible that the assumed high biological age among the sub-elite players could have affected the results as well. Due to the limited amount of participants in this paper the results are not representative for the entire population. Therefore, comparing a bigger group of elite and sub-elite soccer players is of big interest.

Sammanfattning

Fotboll är en populär idrott som utövas av barn, ungdomar, män och kvinnor världen över. Sporten kräver ett flertal fysiska färdigheter så som uthållighet, styrka, rörlighet, snabba riktningsändringar och temporegleringar. Elitfotbollsspelare tränar de här kvalitéerna för att förbättra sin prestation, förebygga skador och klara av den tävling- och träningsvolymen som de ställs inför. Den här studien jämför kroppsliga och fysiska profiler i ett junior-elitlag och ett senior-elitlag från samma svenska fotbollsklubb. Syftet med undersökningen är att upptäcka eventuella skillnader och att belysa förbättringsområden i processen vid förberedelse av junior-elitspelares övergång till senior-elit. Resultatet visade en signifikant skillnad i kroppsfett (Senior-elit: 13.3 ±2.6 vs junior-elite:15.6 ±2.7 och fettfri massa (66.4 ±7.6 vs 59.9 ±3.8 kg). Signifikanta skillnader upptäcktes även i rörlighet i både vänster (147.1 ±8.5 vs 157.1 ±4.7°) och höger (145,1 ±8.4 vs 155 ±4.1°) quadriceps. Ingen signifikant skillnad fanns i styrka mellan de två deltagande grupperna. Ålder och antal aktiva år i sporten kan vara en förklaring till skillnaderna i kroppssammansättning. Juniorspelarna angav fler träningstimmar än seniorerna vilket kan vara en av orsakerna till att det inte fanns några skillnader i styrka mellan grupperna. Det är även möjligt att juniorerna har en relativt hög biologisk ålder vilket i sin tur kan ha påverkat resultatet. På grund av få deltagare i studien är resultatet inte överförbart till hela populationen. Att jämföra en större grupp seniorer och juniorer vore därför ytterst intressant.

Table of Content

Foreword

We would like to thank our supervisor Lennart Gullstrand for the help and support during the writing of this paper. Stefan Grau for the support and encouragement, Andreas Lundberg Zackrisson and Jonatan Jungman for the help with tests and statistics and Mikael Gustafsson for the work with the iDXA scans. Your involvement has made this paper possible and we have learned a lot. Thank you.

Work assignment	% by writer Patrik, Simon and Josefine
Planning	33/33/33
Literature search	33/33/33
Data collection	33/33/33
Analysis	25/50/25
Writing	20/40/40
Layout	25/50/25

Introduction

Soccer is the most popular sport of today (Reilly, Bangsbo, & Franks, 2000). Children, adolescents, men and women participate at various levels all around the world. The sport is played on a field (length: 100-110, width: 64-75 m) covered with natural or artificial grass and requires one ball, two goals and two teams with eleven players each. One standard game is 90 minutes long divided into two halves of 45 minutes each. On a professional level research tells us that the players run an estimated distance of 10-12k within the intensity of 80-90% of max heart rate which in other terms could be described as quite close to the anaerobic threshold. During these 10k the professional soccer players perform several explosive movements other than just running such as jumping, tackling, changing pace, changing direction and sustained muscle contractions in order to control the ball against their opponent (Stølen, Chamari, Castagna, & Wisløff, 2005). Being a soccer player requires multiple skills as the game is built on tactics, technical- and physical performance (Gil, Ruiz, Irazusta, Gil, & Irazusta, 2007).
The physical requirements differ among non-elite and elite soccer players and also depends on what position the player have on the field. Endurance might be the first thing to consider important when describing the physical profile of the sport but strength and power is not to be overlooked. Stølen et al. (2005) states the three qualities as of equal value. Being physically fit is well related to greater performance in soccer. It also helps the players to cope with a heavy training and game load, benefits recovery and prevent injuries (Hoshikawa, Iida, Muramatsu, Nakajima, Fukunaga, & Kanehisa, 2008). Endurance, strength and power is gained from soccer practice and game play but it is possible to enhance sport specific performance by adding extra strength and conditioning training separately (Gil-Rey, Lezaun, & Los Arcos, 2015; Suchomel, Nimphius, & Michael, 2016). Strength training as an example improves sprinting and jumping and quick change of direction ability (Suchomel, Nimphius, & Michael, 2016). In soccer the lower extremities are the most used muscles which means that great strength is essential to perform the required skills and movements repeatedly without getting injured (Lehance, Binet, Bury, & Croisier, 2009). This is mainly done during the preseason when preparing the players for upcoming series and cups but is still performed during in season to maintain fit.

In professional soccer in Sweden the clubs have the economy to hire a strength and conditioning coach, preferably with great experience and education. This provides the players with the opportunity to develop their physical development and maintenance compare to teams that do not have a qualified strength and conditioning coach. Only a few divisions below the top series the soccer organizations are built on voluntary work. In kids and adolescent's soccer the coaches and team leaders are mainly parents. Their level of knowledge is based on their own experiences as soccer players and in some cases additional coach education provided by the Swedish soccer federation (SvFF). Limited of resources may contribute to a lower standard regarding training, both in soccer, strength and conditioning in which inhibits the kids and adolescents fully potential of physical development to become better and healthier soccer players (Reilly, Bangsbo, & Franks, 2000). The lack of strength and conditioning training also increases the risk of injury, both acute and overuse injuries (Arnason, Sigurdsson, Gudmundsson, Holme, Engebretsen, & Bahr, 2004). Since the coaches do not get any payment in return of their work it may also affect the amount of time they choose to spend on helping the team. Soccer training and matches are prioritized and strength and conditioning training then falls behind. One other negative outcome to this is that the players who are up for transition to elite or senior play might not be physically prepared when that day arrives.

Physical demands on the players should be applied with an interest of predicting injuries, enhancing performance as well as preparing those who want to succeed on a professional level.

Only a few studies have been examining differences between sub-elite and elite soccer players, although equal research is to be found based on other team sports such as ice hockey, rugby and Australian football. Each report showing similar results arguing that elite players are more fit than sub-elite players meaning they, are stronger, faster, more explosive, have better endurance, higher VO_2max and have more lean body mass and lower fat percentage (Veale, Pearce, Buttifant, & Carlson, 2010, Gabbett, Kelly, Ralph, & Driscoll, 2009, Ross, Gill, & Cronin, 2015). There are several explanations as well as suggestions regarding these findings including age, time of participation in the sport, training volume and intensity, game intensity, playing position, coach competence, quality of training, height and weight to mention the most highlighted factors (Veale, Pearce, Buttifant, & Carlson, 2010). Transitioning from sub-elite to elite can therefore be a problem. If players move up to a team with greater over all physical abilities, we can assume that these athletes are facing several risks in terms of injuries and burn out. Addressing body composition and physical development in the sub-elite teams is very helpful when optimizing the training to fully prepare the players for an upgrade (Veale, Pearce, Buttifant, & Carlson, 2010). Using the results of fitness tests and body composition from top elite players as guidance when developing younger players could also be of great value. Preparing the athletes for transition to a higher level of play has more benefits than just sustainability and health. It also helps the work of the coaches in the top teams when receiving players who are already equal or not too far behind to the rest of the team players. Great physical differences can complicate the work in terms of moving forward and develop a whole team physically. When unprepared players arrive they have to be familiarized with a new way of exercising and depending on how far behind they are physically it can cost the coach a lot of time. This type of research can provide useful information to coaches and clubs in their work to develop high performance physiques. It can also benefit players by giving them information about how the demands of being a professional elite soccer player. Especially the younger players whose aiming for an elite career.

Definitions

Anthropometric includes length, weight and body composition. In this paper elite sport is defined as; Sport that is practiced on international or national top-level and the division right below the highest division. The definition is adopted from Riksidrottsförbundet (2009) and is the definition that the authors of this paper agreed upon. Sub-elite is defined as youth players playing on a youth elite level with chances of transitioning to senior elite level. Lean mass is defined as all body mass except fat mass. Active mobility is the mobility reached with no outside force or help from another person. Passive mobility is defined as maximum mobility achieved whilst relaxed and allowing an outside force to move limb joints to their maximum angular positions.

Purpose and Hypothesis

The aim of this study is to compare strength, mobility, body composition and training volume in a sub-elite- and an elite soccer team from the same club. The purpose of this comparison is to determine possible differences and locate areas of improvement in the process of preparing the sub-elite players for transition to the elite team. The hypothesis of this study is; (1) The senior players have a more developed physique with a lower percentage of body fat and more lean mass (2) The elite players are stronger than the sub-elite players and (3) The difference between dominant and non-dominant leg is less significant among the elite players.

Background

Body Composition

Using body composition to measure the progress among athletes has become more desirable during the past years, both in sports science and requested by coaches and management of sport clubs. Using the Lunar iDXA as a tool to measure the effects on body composition from training and diet has proven to be a tool for achieving a reliable result. Although it is only a small minority of the athletes that will get the chance to use the Lunar iDXA due to costs and availability of the machine (Nana, Slater, Stewart, & Burke, 2014). The iDXA produces a three-component model of body composition. The scan produces result that show lean mass, fat mass, bone mass and bone mineral content. Other advantages specific for athletes may be the assess of both whole-body and regional areas where the iDXA estimates both fat and fat-free mass for different body parts (Bilsborough, Greenway, Opar, Livingstone, Cordy, & Coutts, 2014). It can be useful to see differences between the dominant and non-dominant body parts as well as it allows follow up on results from specific training, diets or injuries (Milsom, Naughton, O'Boyle, Iqbal, Morgans, Drust, & Morton, 2015; Suchomel, Nimphius, & Michael, 2016). The measurements of an iDXA body scan can help tracking the physical development throughout the season as well as offering important information when trying to predict injuries. When scanning young athletes this tool also provides essential changes caused by maturation (Veale, Pearce, Buttifant & Carlso 2010). While the iDXA measures the body composition it does not reveal any information about the performance level of the athlete but more indications on how well developed the body is. A high muscular strength has shown to be an important factor that improves sport specific skills like sprinting, jumping and quick changes of directions, but also the general performance level in the sport (Suchomel, Nimphius, & Michael, 2016).

Training Volume

Training in soccer has more effects on the athletes than just technical and tactical skill development. The training and more specifically, the training load has an essential impact on physical abilities such as skeletal muscle strength, power and aerobic fitness (Gil-Rey, Lezaun, & Los Arcos, 2015). The progress gained from training is highly dependent on the intensity of the training as well as the individual response among the athletes (Wrigley, Drust, Stratton, Scott, & Gregson, 2012). There are two types of training loads that should be considered in all physical training. External and internal training load. External training load is the training planned and provided by the coaches and the internal training load is the actual physiological stress by the perceiver of the training (Malone, Michele, Morgans, Burgess, Morton, & Drust, 2015). Brink, Nederhof, Visscher, Schmikli, and Lemmink (2010) investigated the relationship between training load, recovery and field test performance on 18 years old male elite soccer players. They found that the players trained and played 394.4 ± 134.9 minutes during a typical in-season week. Using two separate scales they estimated the rate of perceived exertion and the quality of recovery by letting the soccer players fill in a training and recovery log after each practice. The results of this study also showed that more training hours equals better performance. It has become more popular to measure training load and response on an individual level using technical devises both in research as well as within the soccer clubs. Malone, et al. (2015) used a GPS system on each participant to track pace and distance during each activity in English premier league players. Training load differs among players depending on various reasons, for example time of match play, age group and team level (Gil-Rey, Lezaun,

& Los Arcos, 2015). Malone, *et al.* (2015) found that elite soccer players have a higher training load than non-elite players when comparing training load and changes in physical performance.

Isometric strength

At the time when this paper is written there are no standardized strength test protocol for soccer players. Comparing results from tests is therefore difficult (Stølen, Chamari, Castagna, & Wisløff, 2005). Tests that are used varies from the regular weighted back squat, the counter movement jump, dynamic machines and different types of sprints (Stølen, Chamari, Castagna, & Wisløff, 2005; Suchomel, Nimphius, & Michael, 2016; Hoff, Kemi, & Helgerud, 2005; Hoshikawa, et al., 2008; Lehance, Binet, Bury, & Croisier, 2009). As Suchomel et al. (2016) describes as a marker for greater athletic performance is the ability to squat twice one's body mass, however we do not know how well the squats are performed as different criteria's are used from the one supervising the tests. Testing elite soccer players with a standard protocol in a controlled environment would also be a challenge. The need for transporting the players to the machines or the machines to the players is an issue that requires a lot of time, effort and logistics. Hence the test protocols and equipment used varies between studies (Hoff, Kemi, & Helgerud, 2005; Hoshikawa, et al., 2008). No known studies included the machines from David Health solutions have been found except the master thesis by Jungmalm & Zackrisson (2015). They measured angular position of different joints is the angles recommended by the manufacturer. The underlying data for the angular positions is confidential and not available. Comparing different results measured on different machines is therefore not a fully reliable comparison. Still the differences between the test subjects might be trustworthy. To replicate studies is therefore a limitation given that the supply of equipment is scarce. Measuring isometric strength is however well recommended since it excludes an eccentric phase and therefore lowers the possibilities of injuries and delayed onset muscle soreness (Thorborg, Semer, Petersen, Madsen, Magnusson, & Hölmich, 2011). This benefits scientific research when testing active professional athletes. Strength related research conducted on soccer players is mainly focused on the lower extremities such as the knee extensors/flexors and hip adductors/abductors. There has also been an interest in comparing preferred and non-preferred leg since most soccer players kick the ball more frequently with one leg. Rouissi, Chtara, Owen, Chalali, Chaouachi, Gabbett & Chamari (2016) found the dominant leg to be stronger than the non-dominant leg when testing voluntary isometric strength in knee extensors/flexors and hip abductors. The same findings appeared in Thorborg *et al.* (2011) research when both hip abductors and adductor in dominant leg was stronger than the non-dominant leg. A different study testing isokinetic strength in knee flexors/extensors showed the opposite result with greater strength in the non-dominant leg (Rahnama, Lees, & Bambaecichi, 2005).

Mobee Fit System

The Mobee Fit Device is a new high-precision sensor technology offering the ability to measure the mobility status. The muscle groups measured for soccer players were the; (1) the hip flexor, (2) the hamstring muscle, (3) the adductors, (4) the calves and (5) the quadriceps muscle. The test leader had different instructions for how to measure each muscle group, following the protocol provided by the manufacturer. The complete test protocol is presented in *appendix 2.1*.

Sub-elite vs elite

Although both sub-elite ant elite soccer players compete at the national elite level in their respective age group and many of the sub-elite players both train and play with the elder there are obvious differences in their physiques (Milsom, et al., 2015; Hoshikawa, et al., 2008; Veale, Pearce, Buttifant, & Carlson, 2010)**.** The two most distinctive differences in body composition seems to be the percentage of body fat and the total amount of lean body mass (Hoff, Kemi, & Helgerud, 2005; Milsom, et al., 2015; Ross, Gill, & Cronin, 2015). The absolute strength differed significantly in most studies to the elite players advantage (Lehance, Binet, Bury, & Croisier, 2009; Gabbett, Kelly, Ralph, & Driscoll, 2009).

The transition from sub-elite to elite soccer

Only a small number of sub-elite athletes make it to the top in soccer. Researchers are starting to find this element of the sport more interesting. Sub- elite soccer players could benefit from more research in this area when making an effort to prepare themselves for the transition to elite teams. Earlier research on sub-elite to elite transition in both individual and team sports tells us that athletes who want to succeed on a professional level believes that there will be a big difference in practice and performance (Stambulova, Franck, & Weibull, 2011). More knowledge about sub-elite to elite- transition would also contribute to many soccer clubs, especially the elite academies in their work towards developing new top athletes. Most studies of today are qualitative research concerning psychological aspects of in-career transitions (Stambulova, Franck, & Weibull, 2011) which includes various factors. Going from sub-elite to elite in sports comes with more changes than just possible heavier training and higher intensive play. It is not unusual for the transition to take place during the step from adolescent to adult including big physical and psychological changes. It also affects psychosocial areas of your life when coming to a new team with entirely new teammates and coaches as well as leaving your parents’ house to become more independent. All these changes could be reflected in the athlete’s performance. Focusing on the anthropometric and physiological requirements in sub-elite to elite transition in soccer there are less available information. Veale, Pearce, Buttifant, & Carlson, (2010) brings up a problem within selection in Australian Football that could be transmittable to soccer. Many players are selected based on observed skill level and understanding of the sport but if they are physically ready is most uncertain. Chronological and biological age plays a big part in anthropometric and physiological changes (Helsen, van Winckel, & Williams, 2005; Buenen & Malina , 1988). Chronological age is when someone is born and biological age is the timing off the development of essential organs and functions of the body such as skeleton, sexual characteristics and peak height velocity (ref). The variation of timing in maturity complicates the judgement when testing athletes that are not equally developed and the sport supposedly loses out on great potential (Vandendriesschea, et al., 2012). The authors of the same report insist to establish a more advanced testing battery where results are analyzed based on the athletes chronological age and maturation status to optimize the outcome during selection for in-career transition. Below sub-elite and elite soccer the players are mostly organized by year of birth. Earlier studies have found children born early in the year to be more successful (Helsen, van Winckel, & Williams, 2005). The differences between grownups who are born early or late during the year are not as evident. Sub-elite and elite soccer are however not organized by age and the athletes can be separated by months or several years. This can potentially create variation in anthropometric and physiological status.

Methods

Design

This study has a quantative comparative cross-sectional design with non-randomized groups. To see differences between groups one test at one time per subject is full plausible (Ejlertsson, 2012). It is also what Bryman (2011) recommends when comparing two different groups.

Participants

Seventeen professional elite soccer players from a team in the highest division in Sweden and thirteen sub-elite soccer players from the same club at the time attending the club's elite soccer academy as well as their school team. Each player was required to conduct four different tests and to complete a survey. The tests consisted of one iDXA-scan, a passive mobility screening, active mobility tests and isometric strength tests. All tests were conducted in April 2016 approximately one week before the start of the competition season, thus the results are not affected by seasonal progression. The mean values (+/-) age, height, lean mass and body composition and for each group are displayed in *table 1.1* and BMI in *table 3.1*. An overview of one week of typical training volume, shown in hours, are displayed in *table 1.2* for soccer (game-time included), physical training (the training provided by their strength and conditioning coach) and other training (the training done on their own, not being provided by a coach).

Table 1.1

Team	*Age (years)*	*Height (cm)*	*Body mass (kg)*	*Body fat (%)*	*Lean Mass (kg)*
Elite	26.6 (±4.9)*	182.4 (±8.3)	80.1 (±10.1)	13.3 (±2.6)*	66.4 (±7.6)*
Sub-elite	17.7 (±1)*	180.8 (±5.8)	74.1 (±6.3)	15.6 (±2.7)*	59.9 (±3.8)*

*Table showing the mean values of age and general body composition. *=Significant differences*

Ethics

All participants were informed about the purpose and design of the study, they were also informed that the participation is voluntary and can be aborted at any time with no obligation to explain why. Main communication went through the strength and conditioning coach of each team. In the sub-elite team, the players who wanted to participate signed themselves up on a list.

Table 1.2

Soccer training	0 h	1-2 h	3-4 h	5-6 h	7-8 h	9-10	11 h +
Elite	0	0	1	0	2	5	9
Sub-Elite	0	0	0	0	1	3	9
Physical Training	0 h	1-2 h	3-4 h	5-6 h	7-8 h	9-10	11 h +
Elite	1	7	8	0	1	0	0
Sub-Elite	0	7	5	1	0	0	0
Other Training	0 h	1-2 h	3-4 h	5-6 h	7-8 h	9-10	11 h +
Elite	7	9	1	0	0	0	0
Sub-Elite	3	10	0	0	0	0	0

A table over training hours showing the frequency of answered hours in the survey given to the players.

Search methodology

The electronic databases used were PubMed, sport discus and googleschoolar and all articles were searched and downloaded between March 20 and April 20, 2016. There was no limitation considering when the articles were published. The keywords used were ”*junior, senior, male, elite, body composition, soccer, football, players, muscle, balance, strength, mobility, idxa, dexa, dxa, training load, physical development, demands, differences, age, maturation, transition*” in various combinations. After reviewing the articles, a total of 48 articles and sources were included in the paper. To match the inclusion criteria, the articles were carefully read and only articles were the participants were male elite or sub-elite players were accepted. Due to the limited articles of relevant strength and mobility tests articles comparing elite and sub-elite athletes were accepted after reviewing and approving the method used. Regarding articles about body composition only articles using iDXA-measurements were accepted. Only articles published in English or Swedish were used in this paper.

Data analysis

The statistic program used was *IBM SPSS statistics version 22*. Variables for each test were created and named, the data was sorted accordingly. Descriptive statistics were calculated for all demographic data. The test used for calculating the level of significance was the Mann Whitney-test due to the data was not normal distributed. All data was made anonymous when transferring the data from paper to the digital tools. When calculating the athletes body mass index (BMI) a BMI calculator was used (Wiklund, 2016) and for the exact age of each subject the formula (12/10)*months+years was used. For half the players, mainly from the elite team, the exact age was calculated automatically using the DXA-scan. The tables were created in Microsoft Office Word 2016 and the figures in Microsoft Office Excel 2016.

iDXA

For the body composition scan a Lunar iDXA model 16 was used (*appendix 3)*, the software version at the time was version 16. The iDXA-scans was scheduled between 7 am and 10 am for all participants and all scans were performed by the same trained technician. They were instructed to complete the scan on an empty stomach including no intake of fluids. They were also instructed not to perform any form of exercise before the scan. Height and weight was registered for each subject before the procedure. They then performed the scan in their underwear. They were positioned in a supine position on the table with their thumbs pointed upwards and a belt keeping their feet together as instructed by the trained technician according to the procedure explained in the manual. They were instructed to lay completely still and not to talk during the scan. Each scan took approximately seven and a half minutes.

Mobee Fit System

In preparation for the tests the authors, with guidance from master students, practiced with the device at four different occasions. Each practice session lasted between 45-75 minutes. One of the authors was selected to perform all tests ensuring little variance in the result. When the actual testing began one of the master students was present at the first session. To ensure the procedure went according to plan.

The Mobee Fit System tests were conducted in the strength and biomechanical lab at The University of Gothenburg. The device used in this study were from Mobee Fit System (AG, 2016). The test protocol included measurements (°) of hip flexor muscles, hamstrings, adductor muscles, calves and quadriceps. All the tests were conducted by same three test leaders for both the elite players and the junior players. One test leader managed the Mobee device whilst one of the test leaders controlled that the players performed the tests correctly not compensating any lack of mobility with other joints than the one being tested. The third test leader managed the protocol and noted the angles at each test (*appendix 2.2)*. The tests were conducted between 7 am to 10 am, 11 am to 3 pm divided on separate days. The players performed two repetitions in each test. The tests are passive mobility tests were the test leader controls the movement, instructions on how to execute each test is presented in *appendix 2.1*. The test leader attached the Mobee device on the black strap and fastened it around each measured muscle with one exception. During the measurements of the calf muscles the test leader held the device in place with his hands. The Mobee device is highly sensitive and should be practiced by the test leader before using it on the actual participants. Before the measurements the players were instructed to keep their back against the bench at all time and to not dropping the hip during the movements. If the players arched their backs or dropped their hips during the movement, the angle at that moment were considered to be their maximum mobility.

The procedure of the testing in the following order, (1) the hip flexor, (2) the hamstring muscle, (3) the adductors, (4) the calves and (5) the quadriceps muscle, is described in the following text. (1) The hip flexor: the patient was positioned in his back on the table, the tailbone placed at the edge of the table and their head rested against the table. Test leader placed the Mobee device slightly above the athletes' knee cap pointed downward. Keeping the same angle in the knee joint the test leader lowered the players leg creating an extension in the hip flexor. When the player failed to keep their back against the bench the angle was documented. (2) The hamstring muscle (Ischiocrural muscle): the test leader positioned the player on his back on the table with the heels outside the edge of the table. The arms positioned on the chest, with 180° angle in both knee joints and the ankle were held at a 90° angle. The test leader placed the Mobee device five centimeters above the lateral malleolus. The players were instructed to keep their back flat against the bench and to keep their legs straight at all time. The second test leader controlled that the back was against the bench and the third test leader kept the inactive leg straight by applying a light pressure to the knee. The first test leader lifted the leg upwards while keeping it straight to the end position. (3) The adductor muscles: the patient was positioned on their backs on the side of the table with their heels outside of the table. The player's arms were instructed to rest their arms on their chest. The Mobee device was placed on the thigh slightly above the kneecap. The legs were placed with a 15° angle in the hip with the test leg kept straight following the edge of the table. The test leader kept the leg straight while increasing the angle of the hip by moving the leg laterally away from the body. (4) The calves: The Mobee device was placed in the arch of the foot. During this test the Mobee device was handheld. The calves were tested by letting the players perform a plantar flexion. No passive force was applied in this test. (5) The quadriceps (Straight Thigh muscles): The players were positioned on their stomach on the table with their feet outside of the table. The Mobee device was placed five centimeters above the lateral malleolus and with the arms placed close to the body. The test leader held the leg by the ankle whilst pushing the heel towards the gluteus maximus creating a flexion in the knee.

Isometric strength

The strength tests were conducted in the University of Gothenburgs' strength lab. The machines used were from David Health Solutions. The test protocol included isometric strength tests on the quadriceps, hamstrings, hip adductor, hip abductor, back extension, abdominal flexion and abdominal rotation strength. All tests were conducted with the same test leaders and in groups of two to four players. The tests were performed between 9 am to 5 pm divided on different days. The participant where given no restriction orders concerning practice or match play close to the testing day. Due to the team's training schedule some players did the strength test between 9 am and 11 am before their regular soccer practice or after their practice between 1 pm and 5 pm. The warm up was standardized to five minutes cycling on an 828E Monark exercise ergomedic testing bike with self-chosen resistance and with the instructions from the test leaders to get warmed up. Before each test the participants got an explanation on how the machine worked and the purpose of the specific test. The participants were allowed to see the screen and were instructed to keep their hands on their chest when testing the lower body and hanging by the sides in the back and abdominal testes not allowing the players to use their hand for extra support. They were seated in the machines which were adjusted accordingly to the size of the athletes. When the right adjustments had been done they were strapped with the waist strap attached on each machine. They were given one familiarization attempt and two attempts at maximum effort. If the second maximum test differed more than 10 % from the first attempt a third try were given. All players completed at least twenty-four maximum isometric strength measurements. The test leader cheered and encouraged the players during the tests to motivate them to try harder. The machines and the angles tested is displayed in *table 2.1*. Each player took 30 (±5 minutes) to complete all tests. Some of the elite players had experience with the strength tests due to earlier tests as part of their physiological testing. The complete test protocol can be viewed as *appendix 4*.

Table 2.1

Machine	Muscle	Angle
David 200	Quadriceps (extension)	60º
David 300	Hamstrings (flexion)	30º
David 310	Hip abductor	15º
David 320	Hip adductor	15º
David 130	Abdominal flexion	0º
David 120	Abdominal rotation	30º/-30º
David 110	Back extension	30º

A table describing the machines from David Health Solutions, the region tested and at what angle.

Survey

All participants completed a survey originally consisting of eleven questions. One further question was added in the last minute before the first player answered. All questions were asked by the same test leader; thus the subject did not answer directly on the paper. The test leader asked all questions and explained all questions or answered all question regarding the survey. The test leader wrote down the answer given on individual protocols. The survey was either taken before the mobility tests or before the strength tests. The survey is presented as *appendix 1*.

Results

There was a significant difference (P <0.05) in the amount of body fat (%) between the elite and sub-elite teams (13.3 ±2.6 vs 15.6 ±2.7). A significant difference (P <0.05) in total lean body mass was found when comparing the teams (*table 3.1)* and a high age correlated with a higher lean body mass as seen in *figure 1*. The BMI and age had a significant correlation (P< 0.05), although only a trend was seen when analyzing the difference (P=0.052) see the data presented in *table 3.1*. In both the left leg and the right leg there was a significant difference (P< 0.05) when comparing the total lean mass in the left leg (*table 3.1*) and the total lean mass in the right leg (*table 3.1*). A significant difference in the mobility, measured with both the Mobee fit device (P< 0.01) and the David 200 (P< 0.05), in both the left and right quadriceps was found. When comparing the strength tests no significant differences was found, although a trend was observed when comparing the results in the hip abductors (P=0.051) and in the abdominal flexor (P=0.054). No significant differences were found when comparing the strength between the groups and no significant differences or correlations when analyzing the dominant and non-dominant leg. No significant differences were observed when viewing the relative strength between the groups, as seen in *figure 2*.

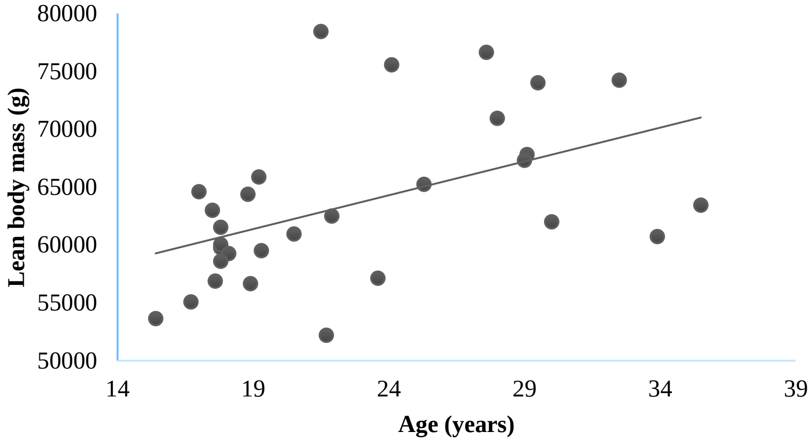


Figure 1. *A significant correlation (P <0,05) between the age and the lean body mass was observed.*

Table 3.1

Team	*BMI*	*Fat mass (kg)*	*Lean Mass (kg)**	*Lean Mass Legs (kg)*	*Lean mass left leg (kg)**	*Lean mass right leg (kg)**	*Lean mass differences (g)*
Elite	24.1 (±1.7)	13.3 (±2.6)	66.4 (±7.6)	23.4 (±3.3)	11.7 (±1.6)	11.7 (±1.8)	353.2 (±260.7)
Sub-elite	22.7 (±1.6)	15.6 (±2.7)	59.9 (±3.8)	21.4 (±1.8)	10 (±2.2)	10.1 (±2.1)	355.7 (±266.2)

*A table showing the differences in body composition between the groups. *=significant differences*

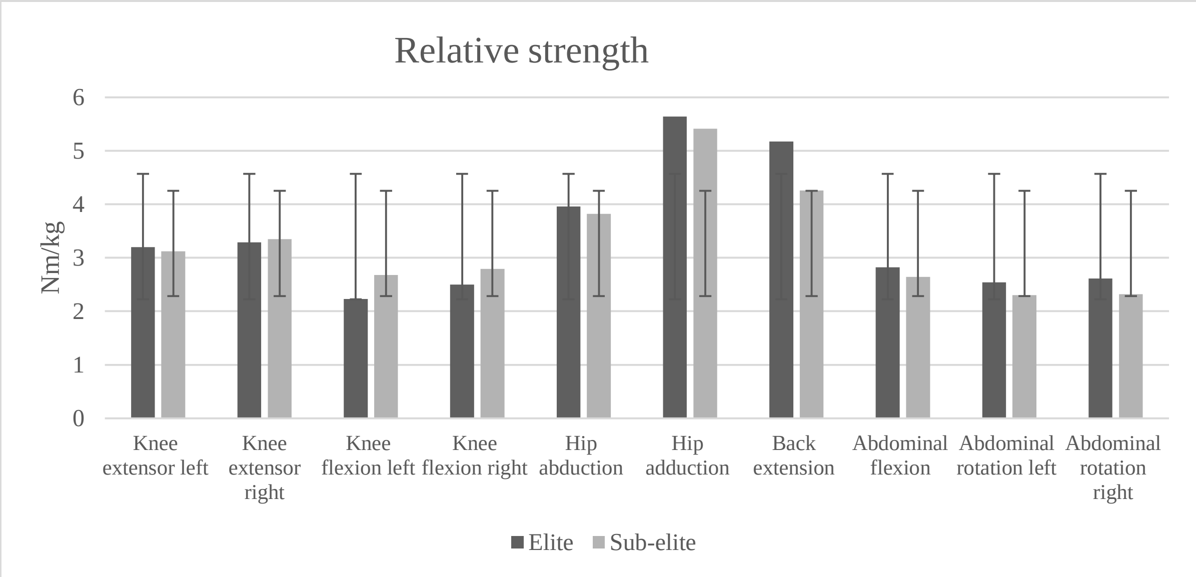


Figure 2. *A comparison in relative strength (Nm/kg) between elite and sub-elite players. No significant differences were found.*

No significant differences or correlations were found when analyzing the training volume, strength or mobility. When comparing the means in absolute strength no significant differences were found, although some trends were observed in favor of the strength in the elite team.

Table 3.3

Team	*Knee extensor left (Nm)*	*Knee extensor right (Nm)*	*Knee flexion left (Nm)*	*Knee flexion right (Nm)*	*Hip abduction (Nm)*	*Hip adduction (Nm)*	*Back extension (Nm/)*	*Abdominal flexion (Nm)*	*Abdominal rotation left (Nm)*	*Abdominal rotation right (Nm)*
Elite	257.3 (±51.2)	264.1 (±48.5)	191.8 (±45.1)	201.3 (±44.1)	339.5 (±79.3)	481.7 (±102.5)	420.1 (±119.1)	224.8 (±40.5)	203.4 (±51.6)	207.2 (±53.9)
Sub-elite	231.7 (±36.1)	248.5 (±31.3)	197.6 (±34.8)	205.9 (±44.4)	282.9 (±50.9)	436 (±55.9)	344.5 (±63)	195.7 (±34.4)	171.1 (±51)	172.3 (±50.2)

This table shows the absolute strength in all isometric tests.

Table 3.4

Team	*Hip Flexor (Left)°*	*Hip Flexor (Right)°*	*Hamstring (Left)°*	*Hamstring (Right)°*	*Adduction (left)°*	*Adduction (Right)°*	*Calf (Left)°*	*Calf (Right)°*	*Quadriceps (Left)°**	*Quadriceps (Right)°**
Elite	105.6 (±11.2)	107.7 (±8.1)	89.2 (±12.4)	93.4 (±13.1)	64.8 (±8.8)	68.1 (±8.2)	20.7 (±7.5)	19.8 (±5.5)	147.1 (±8.5)	145.1 (±8.4)
Sub-Elite	101.3 (±9.3)	103.3 (±10.1)	93 (±7.1)	99.2 (±9.5)	65.7 (±6.1)	69.7 (±6)	19.9 (±5.4)	21.5 (±5.5)	157.1 (±4.7)	155 (±4.1)

*A table showing the results from the Mobee Fit mobility tests. *=significant differences*

Discussion

Method

The iDXA is a valuable tool for measuring body composition among both athletes and non-athletes. It is easy to use and the scan takes approximant seven and a half minutes, an educated supervisor is needed to make sure the scan follows the protocol. It produces reliable results and has been used in a variety of studies. The guidelines when performing a iDXA-scan is to do it on an empty stomach, preferably early in the morning before both eating and drinking but after a visit to the bathroom (Nana, Slater, Stewart, & Burke, 2014). Some of the participants did not follow the guidelines and had breakfast before the scan. This was specifically among the sub athletes, the elite athletes seemed to follow the guidelines given. Even though it can be difficult to get access to a iDXA due to the costs and locations of the machines it has become more frequent used in studies when testing athletes. The results from the scan is not a predictor on how well you can perform in sports. But it can be a predictor for injuries due to the detail of the data from the scan, imbalances in muscle mass between the left and right side can be useful information.

Mobee Fit System

The Mobee Fit System is a new tool for measuring lower body mobility for both athletes or non-athletes. The device has not yet been used in any published studies. The tool is highly sensitive and is therefore quite advanced to use. The test leader has to be very careful and precise when executing the procedure which complicates the standardization between different test leaders. results are dependent on the test leader and may variety between who's handling the device. The test computer program and the remote management is however very easy to use. All tests took approximately fifteen to twenty minutes to conduct the for each person. The guidelines when the players performing the Mobee Fit System were just to follow the instructions from the test leader. Making the players understand the instructions were easier said than done, hence making them following the instructions were as hard as making them understand them. The device was placed in the same position on all players, but the results varied due to the development of the muscle where the device was placed. A more developed muscle affected the measurement and attachment of the device. A better strap with a Velcro would have been a better and easier choice than the click strap used. A positive thing the sensitivity of the Mobee Fit System device, but it could also be a limitation due to the risk of not being able to perform the measurements in the exact same way. One small error could affect the results making the tests unreliable and impossible to use. This could also be a problem for the replication and validity. Every test leader has their own routines during the process which could be a problem for studies to replicate the test in the future. In the future this Mobee Fit System could be a good tool for the strength and conditioning coach to use and check the mobility and flexibility in the lower body on their players. For research the results are too much dependent on who is handling the device to be a reliable tool. To measure mobility for the purpose of science another method is recommended. And at the moment they are no studies that have used Mobee Fit System in research.

The isometric tests

The David Health Solutions machines are convenient tools when testing maximal isometric strength in athletes. Both for research purpose and fitness profiling in sports. The machines simple level of usage most likely decreases the possibility of incorrect or variating procedure between different test leaders. The testing seats are adjustable to fit the length of the athlete and therefore gives all athletes fair conditions when performing the tests. However, the equipment is expensive and only a limited amount of facilities can provide this service. The machines are not mobile and requires the coaches and athletes to schedule an appointment and travel to the facility for the tests. This can be considered as inconvenience. When using the David testing machines for scientific research it can be necessary to adjust the time of testing to the season of the sport and the athletes training and competition schedule. If a cancelation occurs, it can be difficult finding a new date for testing. This happened with 16 players in this study due to match play, injury and oversleeping. We were not able to rebook any of these players for completion of the tests which unfortunately resulted in a smaller testing group than expected. The usage of the David machines in earlier research is most limited and no literature was found where the exact equipment was used besides the master thesis by Jungmalm & Zackrisson (2015). Therefore, it is unclear whether the machines are the recommended tools for maximum strength testing. When using the David machines in this study the researchers acknowledged an advantage among the athletes who had performed the tests before. It mainly saved time while getting correctly seated and not having to explain the procedure in detail. It did not affect the athlete's performance in a noticeable way. The athletes completing the tests for the first time were offered to try the machines before maximal performance to get familiarized with the equipment. This, noticeably provided the athletes with a greater understanding of the procedure. Verbal encouragement by the test leaders and direct access to the result screen is well recommended to improve performance. Several athletes in this study managed to beat the first test result during a second try when seeing their result and receiving verbal encouragement.

Result

The aim of this study was to examine the differences and correlations in strength, body composition and mobility between an elite and sub-elite team from the same Swedish soccer club. This paper was based on three hypotheses (1) The senior players have a more developed physique with a lower percentage of body fat and more lean mass (2) The elite players are stronger than the sub-elite players and (3) The difference between dominant and non-dominant leg is less significant among the elite players. The first hypothesis was confirmed whilst the second and third remain hypotheses to test for future research. The results confirmed what Milsom *et al.* (2015) and Bilsborough *et al.* (2015) showed in their study, elite players have more lean mass and less body fat compared to sub elite players. Although the data collected is from within the same soccer club and with a limited amount of participants the result may not be representative for the entire population. As shown in *table 1.1* there was no significant difference in height (182.4 ±8.3 vs 180.8 ±5.8 cm) or total body mass (80.1 ±10.1 vs 74.1 ±6.3 kg) which could show that most the sub-elite players have gone through the puberty and started to get close to their full grown length. The biological and chronical age may be a factor affecting the results. Although there is a significant difference in the chronical age the biological age may not be so different between the two groups. According to research on this matter a player born early in the year is more likely to play at a higher level than one who is born late (Helsen, van Winckel, & Williams, 2005). This could explain a difference in biological age between athletes with same chronological age. The sub-elite group in this study included five players who were born in June and the remaining eight players were equally distributed in early and late months of the year. Time of birth is therefore not a sensible explanation for this case. Based on Beun & Malina´s (1988) review on growth and physical performance it is more likely possible that the sub-elite players have reached a higher biological age independent on chronical age meaning they have more mature and well developed bodies. This could be one reason to why the results of this study showed no significant difference in absolute or relative strength. It could also be dependent on the fact that the sub-elite team reported more training hours than the elite team.

More training hours is proven to enhance performance. Unfortunately, the maximum option on the survey was 11+ hours and cannot be presented in our data. Although all sub-elite players verbally confirmed playing for their school team combined with participation in the club represented in this case. Therefore, they had at least two more training sessions each week compared to the elite team who participated in one team only. One has to take in consideration that the sub-elite team is from the same Swedish soccer club as the elite team, which is one of the best teams in Sweden. The players in the sub-elite team most likely were recruited based on their skill level.

Body compostion

No significant difference in body mass between the groups was observed, although a tendency in BMI (P=0,052) was observed where the elite group were 1,4 points higher on the BMI scale. Comparing two teams that is a somewhat big difference, the elite players also had a significant higher total lean body mass (66.4 ±7.6 vs 59.9 ±3.8 kg) and a lower body fat (13.3 ±2.6 vs 15.6 ±2.7 %). If the BMI is taken in consideration while viewing the differences in the body composition it emphasizes that there is a big difference between the groups. The elite players who have a higher BMI also have more muscles and less fat. Potentially increasing the ability to create power and speed (Arnason, et al., 2004; Lloyd, et al., 2014; Willigenburg, McNally, & Hewett, 2014). An explanation to the significant difference in lean body mass and body fat could that the elite players have been active as soccer players for a longer period of time. Hence giving them more years of training and more years to build muscle mass. Another aspect is the higher intensity on the elite level compared with sub-elite level. The higher the intensity the higher the physical demands which makes the elite players develop more muscle to adapt to the intensity (Stølen, Chamari, Castagna, & Wisløff, 2005). Another factor is the availability of food, the elite players are provided with a higher quality food than the sub-elite players (Ross, Gill, & Cronin, 2015). As Milsom *et al.* (2015) suggest an early establishment of a good nutrition and training program to prepare the youth players for transition to senior elite play. There was no difference in relative strength between the groups as seen in table *3.2*. That could mean that the strength increases linear with the bodyweight.

Isometric strength

In absolute strength there was no significant differences although some trends showing that the elite players performed better in the maximum strength tests. We suspect that bigger groups would have generated a more significant differences in their results (*see table 3.4)*. The elite players were stronger in all tests although not significantly, as research has shown older elite players are stronger than younger sub-elite players (Ross, Gill, & Cronin, 2015; Hoshikawa, et al., 2008; Veale, Pearce, Buttifant, & Carlson, 2010). In this paper the strength in the hip abduction and abdominal flexors showed a tendency in favor of the elite players. Surprisingly the strength in knee flexion, although not significant, were slightly higher in the sub elite team in both the left and right leg (197.6 ±34.8 resp. 205.9 ±44.4 vs 191.8 ±45.1 resp. 201.3 ±44.1 Nm). The elite group were stronger in the both left and right knee extensors (257.3 ±51.2 resp. 264.1 ±48.5 vs 231.7 ±36.1 resp. 248.5 ±31.3 Nm). The imbalance between extensor and flexor muscles is therefore higher among the elite players compared to the sub-elite players, which could be an indicator for higher risk of injury (Willigenburg, McNally, & Hewett, 2014). The imbalance could be an issue for future research to focus on. Sub-elite players should not be stronger than elite players whilst having a better balance between the quadriceps and hamstrings. Imbalances in strength is often the result of one-sided training, one focus in the elite team should be to minimize imbalances to reduce the risk of injury (Lehance, Binet, Bury,

& Croisier, 2009; Rahnama, Lees, & Bambaecichi, 2005). Another interesting result is the mobility in the quadriceps measured with the Mobee device where there was a significant difference in favor of the sub-elite team. This could be dependent on the size of the hamstring muscles hindering a longer range of motion. However, given that the elite players had inferior strength in the knee flexors that is not likely. It could be that more muscle mass in the quadriceps or legs generally decreases the mobility in the knee flexors. Giving that the elite team were both weaker and less mobile in the hamstrings more research should be conducted to get a deeper view of the issue.

Conclusion

A significant difference was found between the groups with the elite players having a less body fat and more lean mass than the sub-elite players. No significant difference was found in maximum isometric strength or mobility apart from a bigger range of motion in knee flexors among the sub-elite players. Due to the limited amount of participant in this study it is of great interest to compare a bigger group of elite and sub-elite soccer players for more reliable and transferable results. It is also recommended to compare groups from different soccer clubs to see results representing the entire population. If you consider game time and position on the field more accurate results could be reached.

References

AG, S. (2016). Retrieved from Mobee-fit: http://www.mo-bee.de/index.php/What_is_mobee_fit.html

Arnason, A., Sigurdsson, S. B., Gudmundsson, A., Holme, I., Engebretsen, L., & Bahr, R. (2004). Physical fitness, injuries, and team performance in soccer. *Medicine & science in sports & exercise*. doi:0.1249/01.MSS.0000113478.92945.CA

Bilsborough, J. C., Greenway, K. G., Opar, D. A., Livingstone, S. G., Cordy, J. T., Bird, S. R., & Coutts, A. J. (2015). Comparison of anthropometry, upper-body strength, and lower-body power characteristics in different levels of australian football players. *Journal of Strength and Conditioning Research, 29*(3), pp. 826-834.

Bilsborough, J. C., Greenway, K., Opar, D., Livingstone, S., Cordy, J., & Coutts, A. J. (2014). The accuracy and precision of DXA for assessing body composition in team sport athletes. *Journal of Sports Sciences, 19,* pp. 1821-1828. doi:10.1080/02640414.2014.926380

Bryman, A. (2011). *Samhällsvetenskapliga metoder* (2 ed.). Stockholm: Liber.

Buenen, G., & Malina , R. (1988). Growth and Physical Perfomance Relative to the Timing the Adolescent Spurt. *Exercise & Sport Sciences Reviews*(16), 503-540.

Busko, K., Gejewski, J., Mazur-Rozycka, J., Michalski, R., & Lach, P. (2013). Strength pro le in young male athletes from different sports. *Biomedical Human Kinetics*, 77-83.

Delahunt, E., Kennelly, C., McEntee, B. L., Coughlan, G. F., & Green, B. S. (2011). The thigh adductor squeeze test: 45° of hip flexion as the optimal test position for eliciting adductor muscle activity and maximum pressure values. *Manual Therapy* , 476-480.

Ejlertsson, G. (2012). *Statistik för hälsovetenskaperna* (2 uppl.). Lund: Studentlitteratur.

Gabbett, T. J. (2006). Performance changes following a field conditioning program in junior and senior rubgy league players. *Journal of Strength and Conditioning Research, 1,* pp. 215-221.

Gabbett, T., Kelly, J., Ralph, S., & Driscoll, D. (2009). Physiological and anthropometric characteristicsof junior elite and sub-elite rugbyleague players, with special reference tostarters and non-starters. *Journal of Science and Medicine in Sport, 12*, pp. 215-222. doi:10.1016/j.jsams.2007.06.008

Gil, S., Ruiz, F., Irazusta, A., Gil, J., & Irazusta, J. (2007). Selection of young soccer players in terms of anthropometric and physiological factors. *Journal of sports medicin and physical fitness, 47*, pp. 25-32.

Gil-Rey, E., Lezaun, A., & Los Arcos, A. (2015). Quantification of the perceived training load andits relationship with changes in physical fitnessperformance in junior soccer players. *Journal of Sports Sciences, 33*(20), pp. 2125-2132. doi:10.1080/02640414.2015.1069385

Helsen, W. F., van Winckel, J., & Williams, A. M. (2005). The relative age effect in youth soccer acrossEurope. *Journal of Sports Sciences, 23*(6), pp. 629-636. doi:10.1080/02640410400021310

Hicks, K. M., Onambele, G. L., Winwood, K., & Morse, C. I. (2016). Muscle Damage following Maximal Eccentric Knee Extensions in Males and Females. *Journal Pone* , 1-18.

Hoff, J., Kemi, O. J., & Helgerud, J. (2005). Strength and endurance differences between elite and junior elite ice hockey players. The importance of allometric scaling. *International journal of sports medicine, 26*(7), pp. 537-541. doi:10.1055/s-2004-821328

Hoshikawa, Y., Iida, T., Muramatsu, M., Nakajima, Y., Fukunaga, T., & Kanehisa, H. (2008). Differences in thigh muscelarity and dynamic torque between junior and senior soccer players. *Journal of sports sciences, 2*, pp. 129-138.

Jungmalm, J., & Zackrisson, A. (n.d.). (2015) Evaluation of isometric strength tests (Master's thesis). Göteborg: Institutionen för kost- och idrottsvetenskap, Göteborgs universitet.

Kondo, H., & Someya, F. (2015). Changes in ground reaction force during a rebound-jump task after hip strength training for single-sided ankle dorsi exion restriction. *The Journal of Physical Therapy Science*, 319-325.

Kopydlowski, N. J., Weber, E. A., & Sekiya, J. K. (2014). Functional Anatomy of the Hamstrings and Quadriceps. In C. C. Kaeding, & J. R. Borchers, *Hamsting and quadriceps injuries in athletes: a clinical guide* (pp. 1-14). New York: Springer Science + Business Media.

Lehance, C., Binet, J., Bury, T., & Croisier, J. L. (2009). Muscular strength, functional performances and injury risk inprofessional and junior elite soccer players. *Scandinavian journal of medicine science sports, 19,* pp. 19. 243-251. doi:10.1111/j.1600-0838.2008.00780.x

Light, N., & Thorborg, K. (2015). The precision and torque production of common hipadductors queeze tests used in elite football. *Journal of science and medicine in sport*. doi:10.1016/j.jsams.2015.12.009

Lloyd, R. S., Faigenbaum, A. D., Stone, M. H., Oliver, J. L., Jeffreys, I., Moody, J. A., . . . Myer, G. D. (2014, April 26). Position statement on youth resistance training:the 2014 International Consensus. *British journal of sports medicine*, pp. 498-505. doi:10.1136/bjsports-20

Malone, J. J., Michele, R. D., Morgans, R., Burgess, D., Morton, J. P., & Drust, B. (2015). Seasonal training-load quantification in elite english premier league soccer players. *International journal of sports physiology and performance*, *10*(4), pp. 489-497. doi:10.1123/ijspp.2014-0352

Milanese, C., Cavedon, V., Corradini, G., De Vita, F., & Zancanaro, C. (2015). Seasonal DXA-measured body compositionchanges in professional male soccer players. *Full Terms & Conditions of access and use can be found athttp://www.tandfonline.com/action/journalInformation?journalCode=rjsp20Download by: [University of Gothenburg]Date: 07 April 2016, At: 02:19Journal of Sports Sciences, 33*(12), pp. 1219-1228. doi:10.1080/02640414.2015.1022573

Milsom, J., Naughton, R., O'Boyle, A., Iqbal, Z., Morgans, R., Drust, B., & Morton, J. P. (2015). Body composition assessment of english premier league players: a comparative DXA analysis of first team, u21 and u18 squads. *Journal of sports sciences*, pp. 33(17). 1799-1806.

Nana, A., Slater, G. J., Stewart, D., & Burke, M. L. (2014). Methodology Review: Using Dual-Energy X-Ray Absorptiometry (DXA) for the Assessment of Body Composition in Athletes and Active People. *International journal of sport nutrition and exercise metabolism, 24*, pp. 198-215. doi:http://dx.doi.org/10.1123/ijsnem.2013-0228

Oberg, B., Ekstand, J., Möller, M., & Gillquist, J. (1984). Muscle strength and flexibility in different positions of soccer players. *International Journal of Sports Medicine, 5*(4), pp. 213-216.

Onishi, H., Yagi, R., Oyama, M., Akasaka, K., Ihashi, K., & Handa, Y. (2002). EMG-angle relationship of the hamstring muscles during maximumknee flexion. *Journal of Electromyography and Kinesiology*, pp. 399-406.

Paine, R., Chicas, E., Bailey , L., Hariri, T., & Lowe, W. (2015). Strength and functional assessment of healthy high school football players: Analysis of skilled and non-skilled positions. *The International Journal of Sports Physical Therapy*, 850-857.

Paine, R., Chicas, E., Bailey, L., Hariri, T., & Lowe, W. (2015). STRENGTH & FUNCTIONAL ASSESSMENT OF HEALTHY HIGH SCHOOL FOOTBALL PLAYERS: ANALYSIS OF SKILLED AND NON-SKILLED POSITIONS. *The International Journal of Sports Physical Therapy*, 850-857.

Rahnama, N., Lees, A., & Bambaecichi, E. (2005). A comparsion of muscle strength and flexibilty between the preferred and non-preferred leg in English soccer players. *Ergonomics, 48*, pp. 1568-1575.

Reilly, T., Bangsbo, J., & Franks, A. (2000). Anthropometric and physiological predispositions for elite soccer. *18*, 669± 683. doi:10.1080/02640410050120050

Riksidrottsförbundet. (2009). *Idrotten vill.* Stockholm: Andrén Holm.

Ross, A., Gill, N. D., & Cronin, J. B. (2015). Comparison of the anthropometric and physical characteristics of international and provincial rugby sevens players. *International Journal of Sports Physiology and Performance, 10*, pp. 780-785. doi:10.1123/ijspp.2014-0331

Rouissi, M., Chtara, M., Owen, A., Chaalali, A., Chaouachy, A., Gabbett, T., & Chamari, K. (2016). Effect of leg dominace on change of direction ability amogst young elite soccer players. *Journal of Sport Science, 34*(6), pp. 542-548.

Sekir, U., Arabaci, R., & Akova, B. (2015, Oktober 18). Acute effects of static stretching on peak and end-range hamstring-to-quadriceps functional ratios. *World Journal of Orthopedics*, pp. 719-726.

Sheppard, J. M., Nolan, E., & Newton, R. U. (2012). Changes in strength and power qualities over two years in volleyball players transitioning from junior to senior national team. *Journal of Strength and Conditioning Research, 26*(1), pp. 152-157.

Stambulova, N., Franck, A., & Weibull, F. (2011). Assessment of the transition from junior-to-senior sports in Swedishathletes. *International Journal of Sport and Exercise Psychology, 10*(2), pp. 79-95. doi:10.1080/1612197X.2012.645136

Stastny, P., Lehnert, M., Zaatar, A., Svoboda, Z., Xaverova, Z., & Pietraszewski, P. (2015). The Gluteus Medius Vs. Thigh Muscles Strength Ratio and Their Relation to Electromyography Amplitude During a Farmer’s Walk Exercise. 157-165.

Stølen, T., Chamari, K., Castagna, C., & Wisløff, U. (2005). Physiology of Soccer:An Update. *Sports Medicine, 35*(6), pp. 501-536.

Suchomel, T. J., Nimphius, S., & Michael, S. H. (2016). The Importance of Muscular Strength in Athletic Performance. *Sports Medicine*, pp. 1-31.

Thorborg, K., Branci, S., Nielsen, M. P., Tang, L., Nielsen, M. B., & Hölmich, P. (2014). Eccentric and isometric hipp adduction strength in male soccer players with and without adductor-related groin pain: an assessor-blinded comparison. *The Orthopaedic Journal of Sports Medicine,, 2*(2). doi:10.1177/2325967114521778

Thorborg, K., Semer, A., Petersen, J., Madsen, T. M., Magnusson, P., & Hölmich, P. (2011). Hip Adduction and Abduction Strength Profiles in Elite Soccer Players: Implications for Clinical Evaluation of Hip Adductor Muscle Recovery After injury. *Amercian Journal of Sports Medicine, 39*(1), pp. 121- 126.

Vandendriesschea, J. B., Vaeyensa, R., Vandorpe, B., Lenoira, M., Lefevre, J., & Philippaerts, R. M. (2012). Biological maturation, morphology, fitness, and motor coordination as part of a selection strategy in the search for international youth soccer players (age 15–16 years). *Journal of Sports Sciences, 30*(15), 1695-1703.

Veale, J. P., Pearce, A. J., Buttifant, D., & Carlson, J. S. (2010). Anthropometric Profiling of Elite Junior and Senior Australian Football Players. *International journal of sports physiology and performance*, pp. 509-520.

Wiklund, A. (2016, 05 01). Retrieved from Räkna ut ditt BMI: http://www.raknabmi.se/

Willigenburg, N. W., McNally, M. P., & Hewett, T. E. (2014). Quadriceps and Hamstrings Strength in Athletes. In C. C. Kaeding, & J. R. Borchers, *Hamstring and quadriceps injuries in athletes: a clinical guide* (pp. 15-29). New York: Springer Science+Business Media . doi:10.1007/978-1-4899-7510-2

Appendix 1 Survey

Age:

years

Height:

cm

Weight:

kg

Years as active

years

Team:

Junior Senior

Position:

Goalkeeper Defense Midfield Forward

Have you been injuried in the last year? Injury = 2 consecutive missed trainings with the team due to injury/pain

Yes No

If yes:

Injuried now Past 3 months Last 4-6 months Last 7-9 months Last 10-12 months

Training volume per week (hours)

Soccer	1-2 h	3-4 h	5-6 h	7-8 h	9-10 h	11 h or more
Physical training	1-2 h	3-4 h	5-6 h	7-8 h	9-10 h	11 h or more
Other training	1-2 h	3-4 h	5-6 h	7-8 h	9-10 h	11 h or more

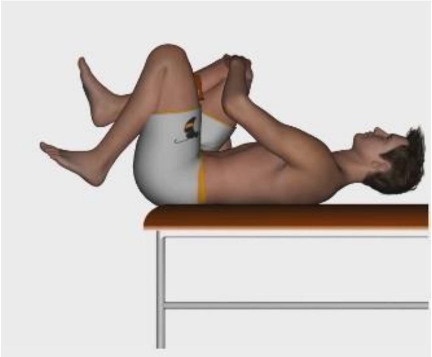
Appendix 2.1 Hip Flexor muscles

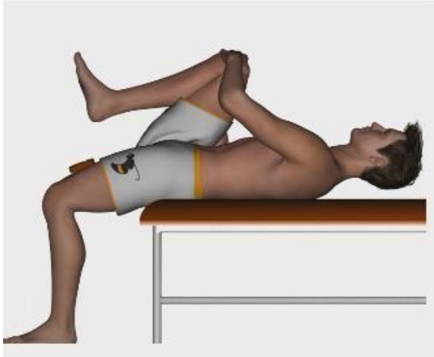
Important:

- Let the patient have two tries for each side (right/left) on each exercise
- Make sure the patient performs the exercises <u>slowly</u>
- Attach the Mobee device on the black strap and then on the patient (except for calves) Make sure you start measuring from 0°. The Mobee device is sensitive.
- The patient is <u>not allowed</u> to arch his/her back or to compensate with the hip when performing the exercises

Hip Flexor muscles

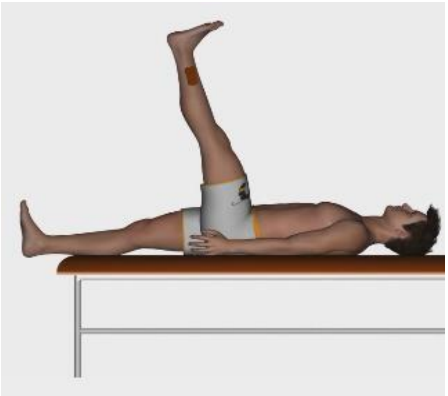
- The patient lies down with his/her back completely against the examining table
- The patients tailbone is placed just at the edge of the examining table
- Make sure the patients head rests against the examining table
- Place the Mobee device so that it points downwards (see arrow on the device) on the patients thigh just above the knee cap





Appendix 2.1 Hamstrings (Ischiocrural muscles)

- The patient lies down with his/her back completely against the examining table, and with the heels just outside the examining table
- Make sure the patients head rests against the examining table, and the arms against the chest The ankle should be in 90°
- Stabilize the side you are not measuring with your hands
- The Mobee device is attached just above (5 cm) the lateral malleolus

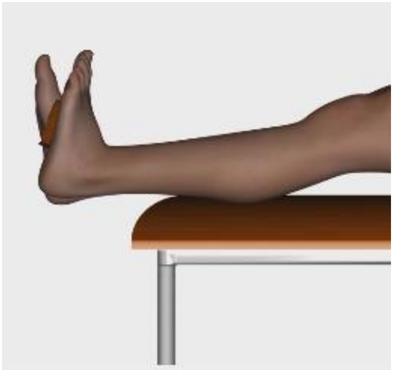


Appendix 2.1 Adductor muscles

- The patient lies down with his/her back completely against the examining table, and with the heels just outside the examining table
- Make sure the leg of the patient you are measuring is close to the edge of the examining table
- The patients arms rests on his/her chest
- Place the Mobee device on the patients thigh just above the knee cap
- Make sure the patient does not rotate the leg you are measuring

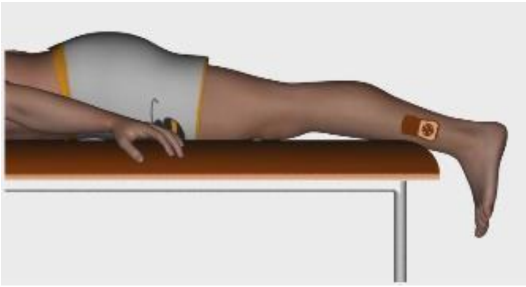
Appendix 2.1 Calf muscles

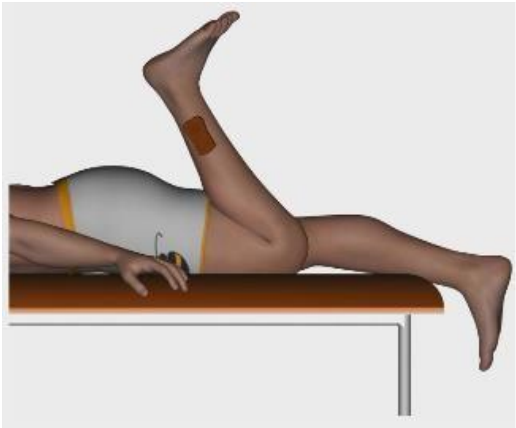
- The patient lies down with his/her back completely against the examining table, and with the heels just outside the examining table
- Place the Mobee device in the middle of the foot of the patient
- Make sure you start measuring from 0°. The Mobee device is sensitive.
- Note that you do not use the black strap for the Mobee device for this measurement



Appendix 2.1 Quadriceps (Straight Thigh muscles)

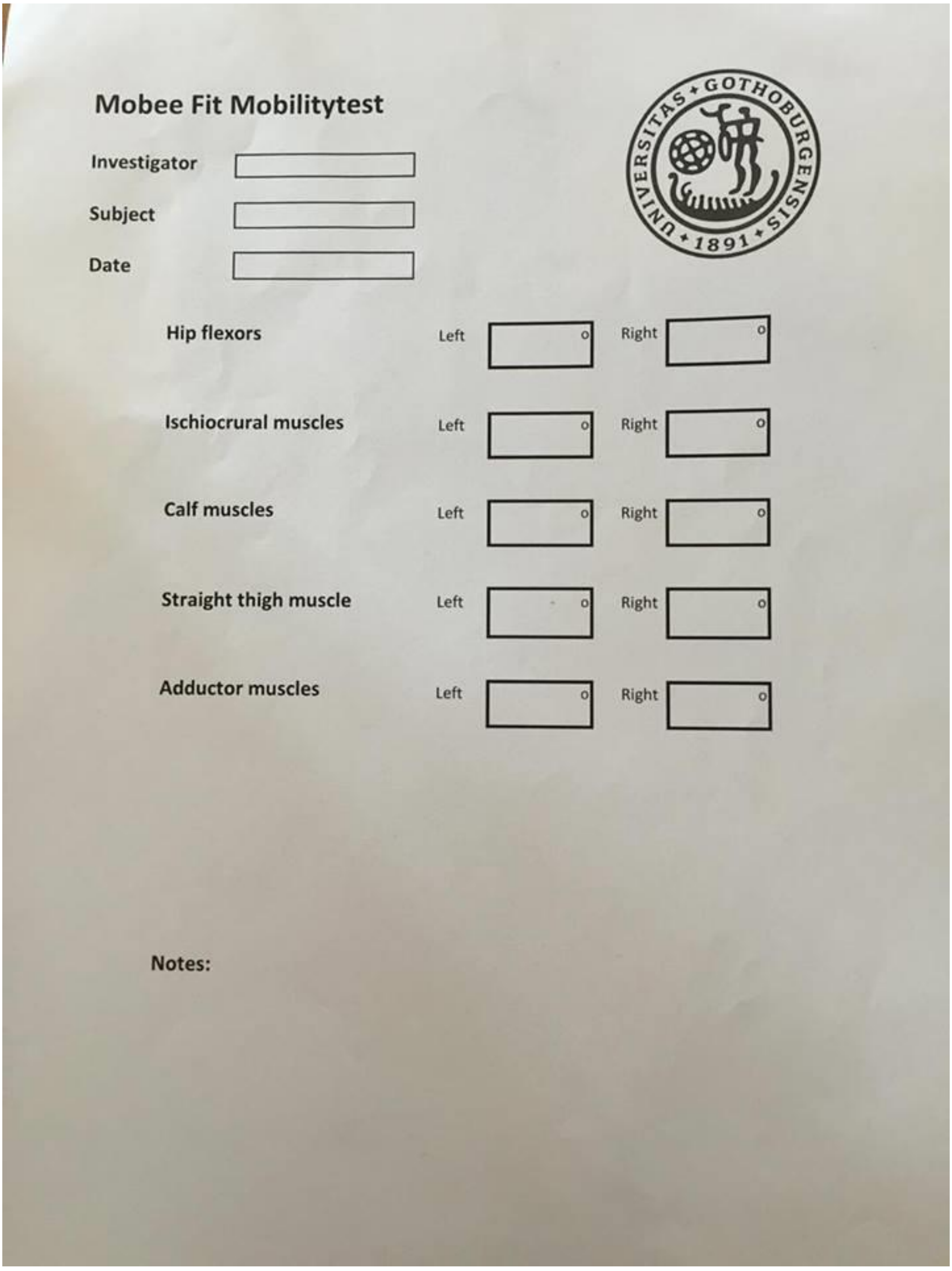
- The patient lies down on his/her stomach, and with the feet outside of the examining table
- Place the Mobee device at the same position as for the measurement of the hamstring muscles
- The patients arms should be close to the body
- Make sure the patient lifts his/her leg up straight and does not rotate the leg in any way





7

Appendix 2.2 Mobee fit test protocol



Mobee Fit Mobilitytest

UNIVERSITAS GOTHOBURGENSIS 1891

Investigator

Subject

Date

Hip flexors	Left	°	Right	°
Ischiocrural muscles	Left	°	Right	°
Calf muscles	Left	°	Right	°
Straight thigh muscle	Left	°	Right	°
Adductor muscles	Left	°	Right	°

Notes:

Appendix 3 Lunar iDXA

GE Healthcare

Lunar iDXA

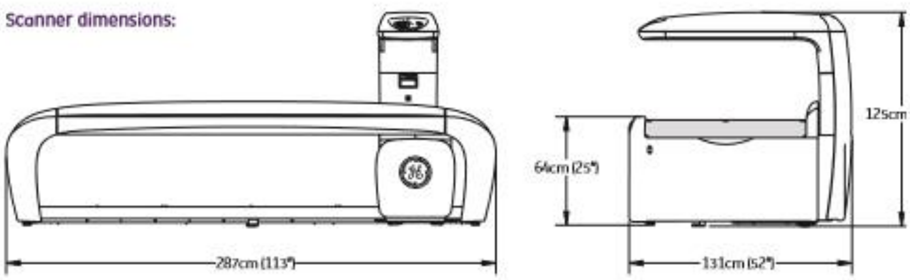
WITH **FORMA** PACKAGE

Tailored for advanced metabolic health assessment

In your search for answers to a patient's health concerns, information is everything. The Lunar iDXA* with Forma package offers our most advanced system to provide the body composition analysis tools to help meet your metabolic health needs.

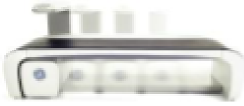
The Lunar iDXA Forma delivers **precise** body composition measurements with a **comprehensive** suite of tools to aid in clinical decision making across all body types. Additionally it also includes **patient-friendly reports** to help monitor progress.

Scanner dimensions:



enCORE v15 - Some features may not be available in all markets.

Lunar iDXA with Forma Package specifications (nominal)



Software applications and features:

○ OPTIONAL

Clinical applications:
- Total body BMD
- Total body and regional tissue quantitation
- Advanced body composition (data visualization, trending & reporting tools)
- ○ *AP spine*
- ○ *Femur*
- ○ *DualFemur*
- ○ *Forearm/supine forearm*
- ○ *Dual-energy Vertebral Assessment (DVA) (lateral and AP)*
- ○ *Fracture risk assessment tool: FRAX***[1,2]
- ○ *Advanced Hip Assessment (AHA)*
- ○ *Orthopedic hip*
- ○ *Pediatric spine/femur/total body*
- ○ *Hand/supine hand*
- ○ *Small animal total body*[3]
- ○ *Spine geometry*
- ○ *CoreScan* (Visceral fat quantification)*

Workflow:
- Previous scan image comparison
- OneVision
- Automatic metal detection
- Image preview
- SmartScan
- ○ *OneScan measurement*
- ○ *QuickView measurement (10sec)*

Analysis & reporting:
- Custom region of interest analysis
- Composer reporting tools
- Custom reference creation
- ScanCheck
- Practice management tools

Connectivity:
- HIPAA secure view
- SQL server
- ○ *DICOM** interface*[4]
- ○ *HL7 interface*[4]
- ○ *TeleDensitometry (e-mail, fax)*[4,5]
- ○ *Multi-User DataBase access (MUDB) (1-3 users)*[4]
- ○ *Multi-User DataBase access (MUDB) (1-10 users)*

Scanner table specifications:

Scanner size	2.87m x 1.31m x 1.25m (113" x 52" x 49")
Scanner weight	360kg (792lbs)
Patient table top height (adjustable)	64cm (25")
Maximum patient weight supported	204kg (450 lbs)
Drive system	stepper motor with reinforced drive belts
Active scan area	198cm x 66cm
Start position indicator	cross laser light (class II, <1mW power)
Pad	washable patient mat, includes paper roll dispenser
Attenuation of patient support table	<1.2mm AL
Communication cable	Ethernet
Scanner leakage current	meets IEC 60601-1 safety standard

Detector specifications:

Detector	high-definition, direct-digital detector

Computer specifications:

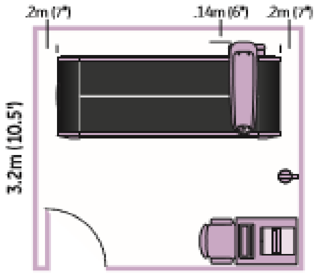
Non-US customers will need to verify that the computer is certified to local requirements. The computer must meet the minimum requirements that follow:

- 2.8 GHz Intel** Pentium** 4 or 2.79 GHz AMD Athlon** II processor
- Windows** 7 Professional (32-bit)
- 2 GB RAM
- 160 GB hard disk
- DVD-R drive
- 17" SVGA monitor with at least 1024 x 768 32-bit color
- External hard drive (data archive location)
- 10/100 Mbit Ethernet port
- Internet Explorer** version 8.0
- Windows-compatible printer
- Adobe** Acrobat** reader

Environmental specifications

Power	100-127 VAC 50/60Hz 20A dedicated circuit 200-240 VAC 50/60Hz 10A dedicated circuit
Consumption	idling 40VA, Scanning 750VA
Distortion	sinusodal waveform, less than 5% THD
Humidity	20%-80% non-condensing
Room temperature	18°C-27°C (65°F-81°F)
Scanner heat output	idling 150 BTU/hr, scanning 1800BTU/hr
Console heat output	approx. 400BTU/hr with 17" monitor
Ventilation	all cooling vents must remain unblocked
Dust, fumes, debris	install system in clean, ventilated area

Minimum room dimensions[6]



The Lunar iDXA is designed to have minimal impact on your practice in both the installation requirements and required operating space. The Lunar iDXA is shown in a 3.35 m x 3.2 m exam room with the included workstation. No operator shielding or special site preparation beyond a dedicated 100-127/200-240 VAC duplex outlet is usually required.[7] The outlet should be placed near the desired location of the operator's console.

General Electric Company reserves the right to make changes in specifications and features shown herein, or discontinue the product described at any time without notice or obligation. Contact your GE representative for the most current information.

GE Healthcare, a division of General Electric Company

Indications for use: The Lunar iDXA Bone Densitometer provides an estimate of bone mineral density and fat and lean tissue mass. The values can then be compared to a reference population at the sole discretion of the physician.

CAUTION: Federal Law restricts this device to sale by or on the order of a physician.

Lunar Product Division:

Americas
GE Healthcare Lunar
Global Headquarters
PO Box 7550
Madison, WI 53707-7550
T: +1-800-535-7339
F: +1-608-223-2482

Europe, Middle-East & Africa
GE Healthcare Lunar
Pollards Wood
Nightingales Lane
Chalfont St Giles
Buckinghamshire, UK
HP8 4SP
info.lunar@ge.com

Asia & Pacific
GE Healthcare Lunar
3/F GE China Technology Park
No. 1 Hua Tuo Road
Shanghai 201203, China
T: +86-21-38777888
(Ext. 60128 or 60480)
F: +86-21-38777451

About GE Healthcare

GE Healthcare provides transformational medical technologies and services that are shaping a new age of patient care. Our broad expertise in medical imaging and information technologies, medical diagnostics, patient monitoring systems, drug discovery, biopharmaceutical manufacturing technologies, performance improvement and performance solutions services help our customers to deliver better care to more people around the world at a lower cost. In addition, we partner with healthcare leaders, striving to leverage the global policy change necessary to implement a successful shift to sustainable healthcare systems.

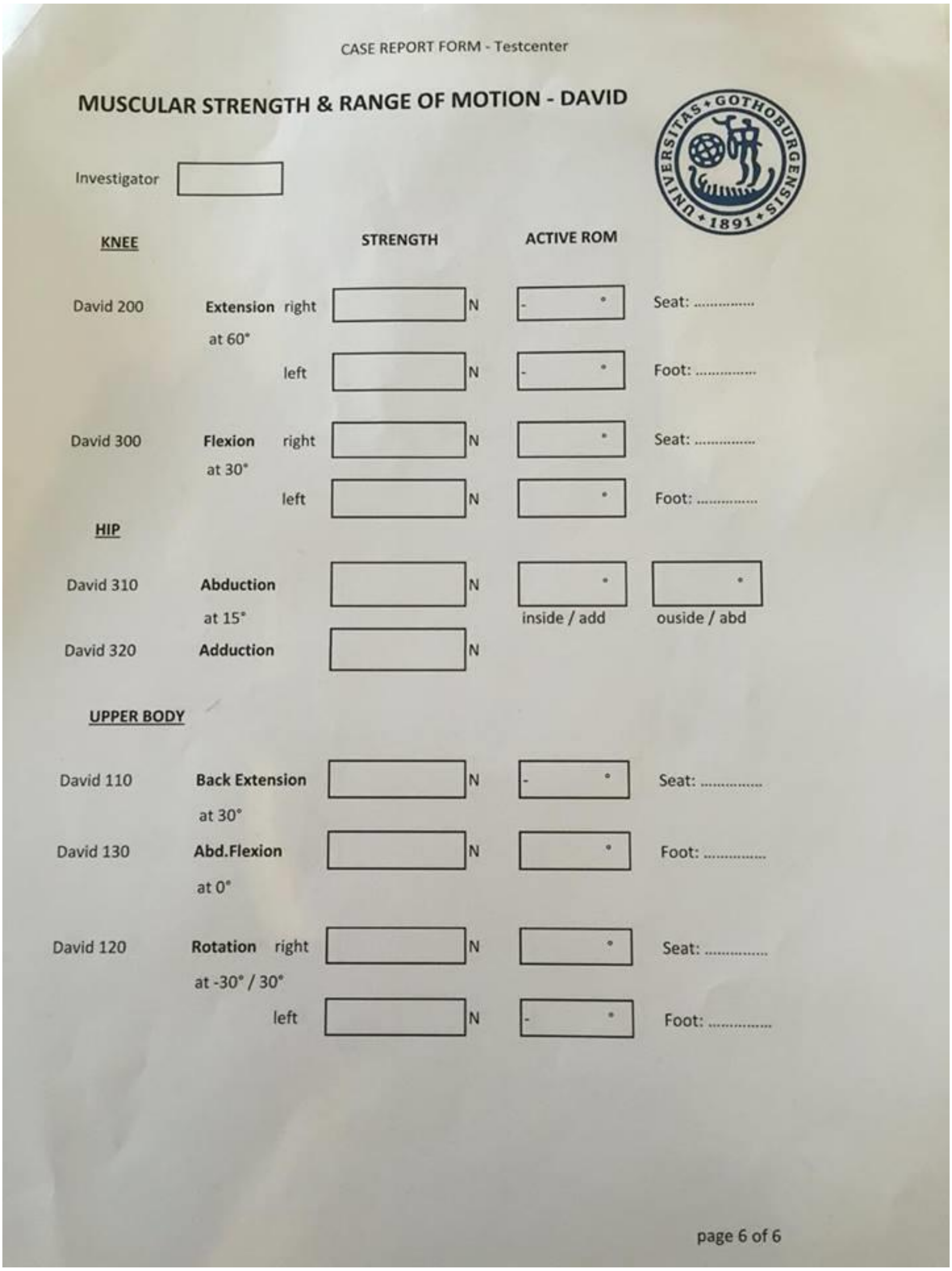
Our "**healthymagination**" vision for the future invites the world to join us on our journey as we continuously develop innovations focused on reducing costs, increasing access and improving quality around the world. Headquartered in the United Kingdom, GE Healthcare is a unit of General Electric Company (NYSE: GE). Worldwide, GE Healthcare employees are committed to serving healthcare professionals and their patients in more than 100 countries. For more information about GE Healthcare, visit our website at ***www.gehealthcare.com***.

1. DVO available in Germany
2. Unavailable in Germany and Japan
3. Laboratory animals only
4. Standard in US, may be optional in other regions
5. Additional hardware may be required for fax capabilities.
6. A small room kit with isolation transformer may be required. Consult and follow local X-ray regulations.
7. Consult and follow local X-ray regulations.

imagination at work

enCORE v15 - Some features may not be available in all markets.

Appendix 4 Isometric tests protocol



CASE REPORT FORM - Testcenter

MUSCULAR STRENGTH & RANGE OF MOTION - DAVID

Investigator

			STRENGTH	ACTIVE ROM	
KNEE					
David 200	**Extension**	right	N	- °	Seat: ....
	at 60°	left	N	- °	Foot: ....
David 300	**Flexion**	right	N	°	Seat: ....
	at 30°	left	N	°	Foot: ....
HIP					
David 310	**Abduction**		N	° inside / add	° ouside / abd
	at 15°				
David 320	**Adduction**		N		
UPPER BODY					
David 110	**Back Extension**		N	- °	Seat: ....
	at 30°				
David 130	**Abd.Flexion**		N	°	Foot: ....
	at 0°				
David 120	**Rotation**	right	N	°	Seat: ....
	at -30° / 30°	left	N	- °	Foot: ....

page 6 of 6